INFLUENCE OF LUMINANCE ON COLOUR BLEEDING ARTEFACTS IN COLOUR IMAGE COMPRESSION

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ABSTRACT

This paper investigates the influence of luminance on colour bleeding artefacts. Colour bleeding artefacts are the distortions due to sub sampling and quantisation of colour images during compression. Performance of the IrfanView™ JPEG and JEG2000 codecs were evaluated for colour reproduction under varying luminance levels. Authors argue that the luminance signal, Y influence the hue of a colour image. Six colour test patterns having same hue and step luminance values were designed and used to compress and reconstruct with the Irfanview™ codecs. The luminance affects the hue of the reconstructed image differently for different hue values. The relationship cannot be generalised that increasing luminance values result in increasing hue errors. At some luminance values, hue did not show any errors. However, in general, with increasing compression ratio the colour bleeding due to the cross luminance effect increases. Based on the proposed methodology, the Irfanview™ JPEG2000 codec outperformed the JPEG codec for colour reproduction.

1. INTRODUCTION

People have been enjoying colour television since 1954 [1]. Analogue colour television systems are based on NTSC, SECAM and PAL colour codecs. The digital television broadcasting systems use different encoding and decoding technologies. In analogue television, encoders were used to form the colour composite video signal (CCVS) which is a combination of luminance and chrominance component signals. The chrominance information can be decomposed into two components which are saturation and hue. Saturation is determined by the amplitude of the colour subcarrier and hue is determined by the phase of the colour subcarrier relative to the colour reference signal known as colour burst (pilot). When analogue or digital video signals are processed, they introduce distortions to the encoded signals.

DG (Differential Gain) and DP (Differential Phase) are two types of distortions in analogue colour television. These are non-linear distortions in the colour component of CCVS due to the level modulation of chrominance on luminance. Differential gain error is the change in the amplitude of the chrominance subcarrier due to a change in the luminance level. Differential phase error is the change in the phase of the chrominance subcarrier due to a change in the luminance level. Differential phase indicates how the hue of a given colour changes when picture brightness changes [2]. Measuring DG and DP for analogue TV is essentially measuring the error in amplitude and phase of a sinusoidal signal as its dc-offset level is varied.

In digital television broadcasting the source encoding is done to reduce the amount of data. The image compression is performed using many techniques to reduce the amount of data within images (intra-coded) and between images (inter-coded). Digital image and video compression results in new form of distortions known as digital compression artefacts.

Though the cross effect of luminance or the intensity on chrominance has been studied for analogue colour television no such study could be found for digital image compression that is used in digital television broadcasting.

2. MOTIVATION

When a yellow colour image that has the hue angle of 168 degrees is compressed and reconstructed, the blue colour patches appear as shown in Figure 1. Blue is the complementary colour of yellow. This large error of approximately 180 degrees may have been influenced by the luminance level.

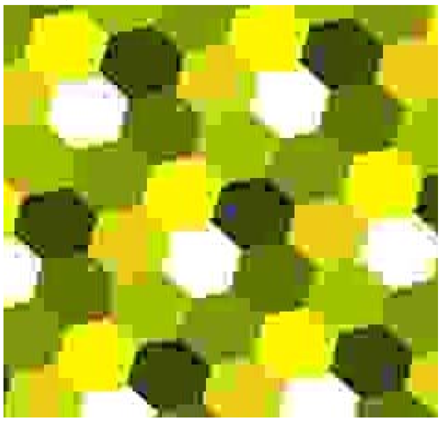

Figure 1 – An enlarged potion of the reconstructed colour image which originally had only yellow as the hue at compression ratio of 210:1.

Colour bleeding is introduced by digital image codecs. Researchers have defined the colour bleeding as the spread of colour information across colour boundaries [3, 4, 5]. Colour bleeding occurs when one colour in a region bleed into or overlap into another colour region across the colour edges inappropriately. This is qualitatively described as the leakage of other colours to a given colour region from neighbouring regions having distinct colours.

In analogue television broadcasting the RGB signals are converted to two colour difference signals Cr and Cb which are defined as [6];

$$Y = 0.299R + 0.587G + 0.114B \quad (1)$$
$$Cr = 0.499\,(R - Y) \quad (2)$$
$$Cb = 0.879\,(B - Y) \quad (3)$$

For the reconstructed image, the value of R, G and B depend on received luminance value Y. Colour can be varied by varying the luminance or the chrominance. Therefore, we can write the colour bleeding as a function of luminance and chrominance. Previous works were concentrated on the effects of chrominance on colour bleeding when the luminance is constant [7, 8, 9, 10]. This research attempts to investigate the effects of luminance on colour bleeding artefacts when the hue is kept constant.

Figure 2 shows the hue distribution of the uncompressed magenta test image. This magenta test pattern has no other hue. But Figure 3 shows that the change of the luminance level will cause the colour bleeding and the other colours appear when the image is reconstructed.

The goal of this research was to identify the non linear behavior of the distortion of colour bleeding in intra-coded digital image and video systems due to luminance variations for different hue.

3. METHODOLOGY

Two aims of this research were to design test patterns for six hue values and then use them to investigate the influence of luminance on colour bleeding artefacts. Three primary colours and the complementary colours of them were used as hue for the experiment.

3.1 Design of Test patterns

Three primary colours R, G, B are used to represent colour in image and videos. Since test patterns are defined based on hue, the values of R, G, B are transformed to hue, saturation and luminance colour space.

Each test pattern has uniformly distributed hue and six distinct luminance levels and white within the image. The hue are three primary colours red, green and blue and their complementaries magenta, cyan, yellow and white. These six colours with six luminance values give a hexagonal tessellation structure with sharp colour boundaries.

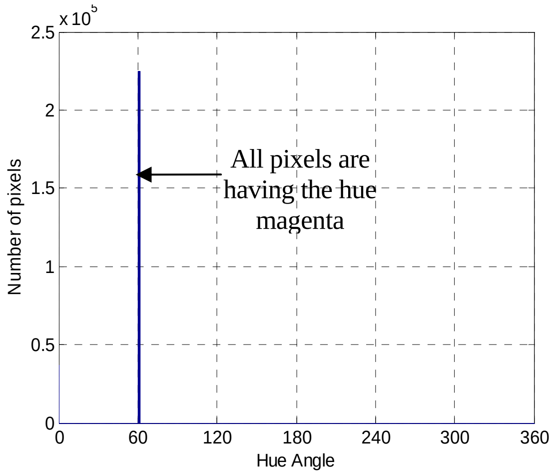

Figure 2 – Hue distribution of uncompressed magenta image

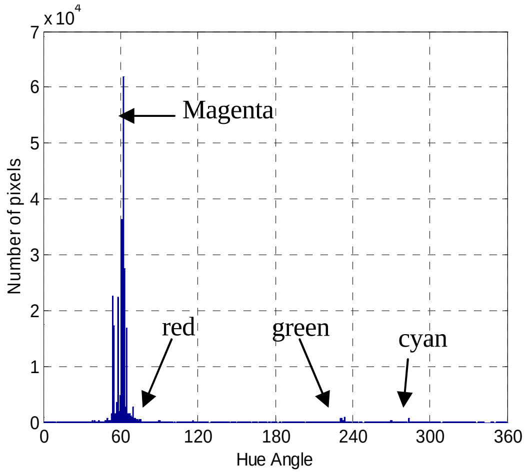

Figure 3(a) – The hue distribution of magenta colour pixels in the reconstructed test pattern.

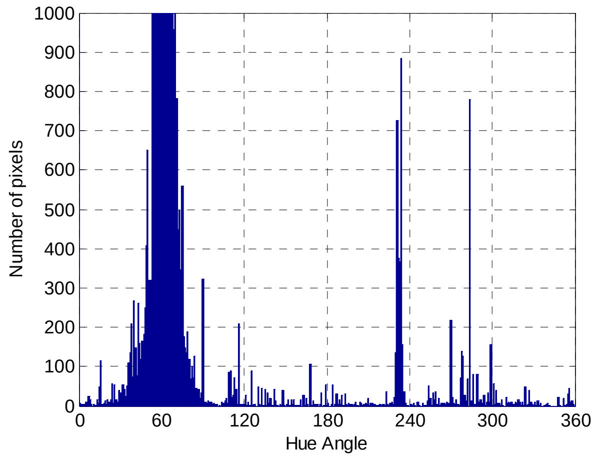

Figure 3(b) – Magnified hue distribution of figure 3(a).

The test patterns were compressed over a wide range of compression ratios and decompressed using the JPEG and

JPEG2000 codecs within Irfanview™ software package by controlling the quality factor.

The quality factor is the only variable available to the user to control the file size. Quality factor was varied to obtain a range of compression ratios. In general, the lower the quality factor the higher the compression ratio and more visible artefacts become. At low compression ratios, the artefacts may not be obvious to the human eye. The reconstructed images were saved as bit mapped files to read within the Matlab™ simulation environment.

Figure 4(a) shows the reconstructed test pattern with magenta hue and at a quality factor of 2 when compressed with the Irfanview™ JPEG codec. Figure 4(b) shows the reconstructed test pattern with the same compression ratio of 200:1 with the Irfanview™ JPEG2000 codec.

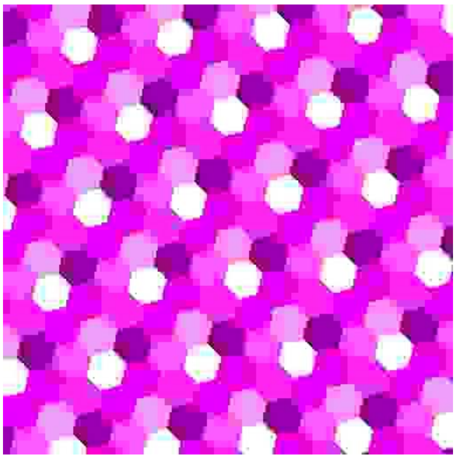

Figure 4(a) - Reconstructed test pattern with magenta hue at a compression ratio of 200:1 when compressed with a quality factor of 2 using the Irfanview™ JPEG image codec.

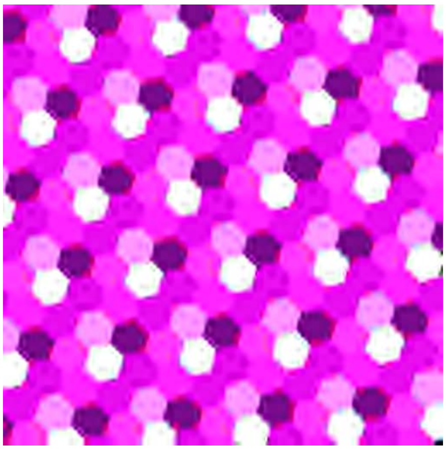

Figure 4 (b) - When compressed with the Irfanview™ JPEG2000 image codec (compression ratio 200:1).

Only two yellow and magenta hues have been chosen for the discussion within the paper due to space constraints.

3.2 Cross Colour Bleeding Metric

Hue of a given colour is the dominant colour component of that colour and it can be represented as an angle in degrees between 0 and 360 in a polar plot. The cross colour bleeding is defined as the spread of the hue angle within a population consisting of regions having one hue contaminated by other luminance after reconstruction and measured by the standard deviation.

$$Hue = \tan^{-1}\left(\frac{0.877[R-(0.3R+0.59G+0.11B)]}{0.493[B-(0.3R+0.59G+0.11B)]}\right)$$

Magenta, red, yellow, green, cyan and blue have 61, 104, 168, 241, 284 and 348 degrees respectively as hue in the each of the original test patterns.

The spread of hue pixels in each colour region (same hue and different luminance) needs to be evaluated separately. An algorithm was devised to calculate individual standard deviation to ascertain the hue spread and to calculate the mean shift value. Firstly, RGB colour image is transformed to hue, saturation and luminance (HSL). The flow chart shown in Figure 5 indicates how the hue images of the original and reconstructed patterns are processed.

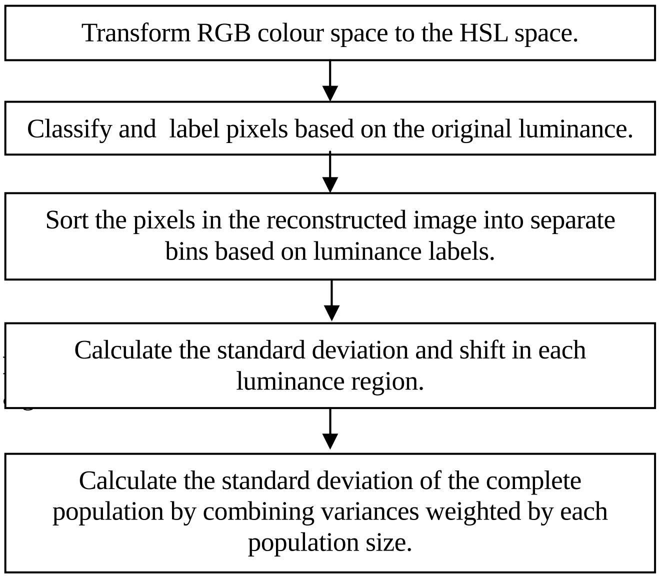

Figure 5 - Flow chart depicting the algorithm to compute spread and shift.

The individual standard deviations represent the hue spread of each hexagonal region under varying luminance levels. This results in six distortion (colour bleeding) metrics. To obtain a single metric for each hue, six metrics were combined.

4. RESULTS

The hue spread and hue shift were computed for each colour test pattern reconstructed using Irfanview™ JPEG and JPEG2000 codecs.

Figures 6(a) and 6(b) show the hue spread of magenta and yellow respectively. These results show that there are no hue errors on luminance level 2 and 6 in magenta and luminance level 3 and 4 in yellow.

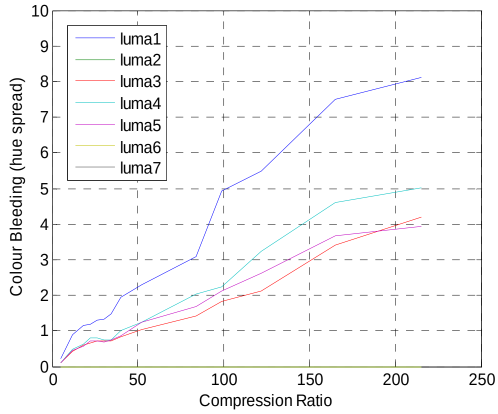

Figure 6(a) – The hue spread in each luminance region of the reconstructed magenta colour test pattern using the Irfanview™ JPEG codec.

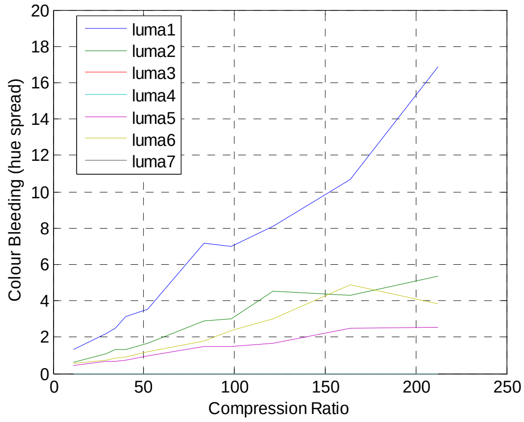

Figure 6(b) – The hue spread in each luminance region of the reconstructed yellow colour test pattern using the Irfanview™ JPEG codec.

Figures 7(a) and 7(b) show the hue shift for magenta and yellow hue test patterns respectively.

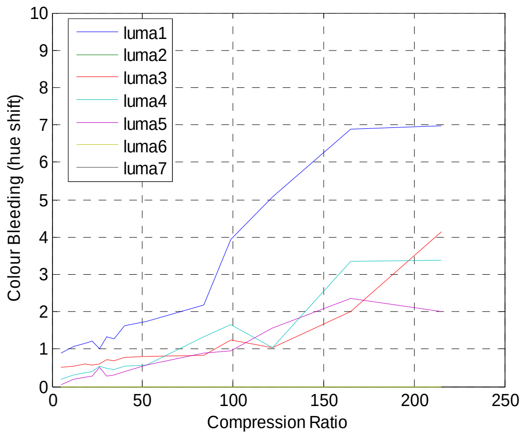

Figure 7(a) – The hue shift in each luminance region of the reconstructed magenta colour test pattern using the Irfanview™ JPEG codec.

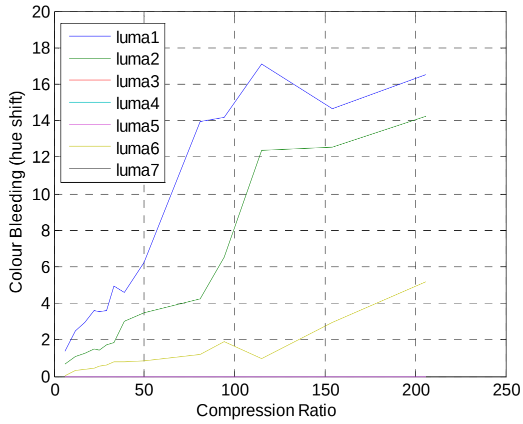

Figure 7(b) – The hue shift in each luminance region of the reconstructed yellow colour test pattern using the Irfanview™ JPEG codec.

When the colour bleeding is compared using the hue spread and hue shift between yellow and magenta, yellow has twice the spread and the shift of magenta approximately.

Figures 6(a), 6(b), 7(a) and 7(b) show that in some cases there are no hue errors at certain luminance levels. This could be a special case where quantisation error is zero. The saturation errors were investigated for magenta colour test pattern with JPEG codec and the results are shown in Figure 8. Figures 6(a) and 7(a) show that luminance levels 2 and 6 in magenta have no hue errors. Similarly Figure 8 confirms that the test pattern is reconstructed without any saturation error. Therefore the reconstructed value of R-Y and B-Y remains same as original values and both hue angle and saturation do not change.

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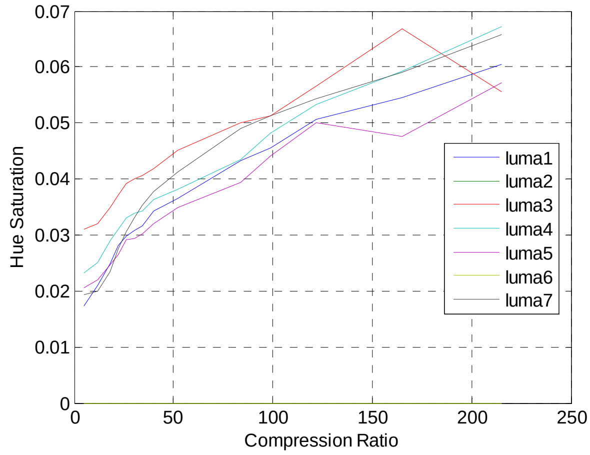

Figure 8 - The saturation spread in each luminance region of the reconstructed magenta colour test pattern using the Irfanview™ JPEG codec.

Figure 9(a) shows the combined hue spread of magenta when the luminance value was changed for each cell with Irfanview™ JPEG and JPEG2000 codecs. Both results show similar trends. Compression ratios above 125:1, JPEG2000 codec performs better and compression ratios below 125:1

JPEG codec performs better and the colour bleeding spread is less compared to JPEG2000.

Figure 9(b) shows the hue spread of yellow with varying luminance based on JPEG and JPEG2000 codecs. Compression ratios above 60:1 Irfanview™ JPEG2000 codec perform better than JPEG.

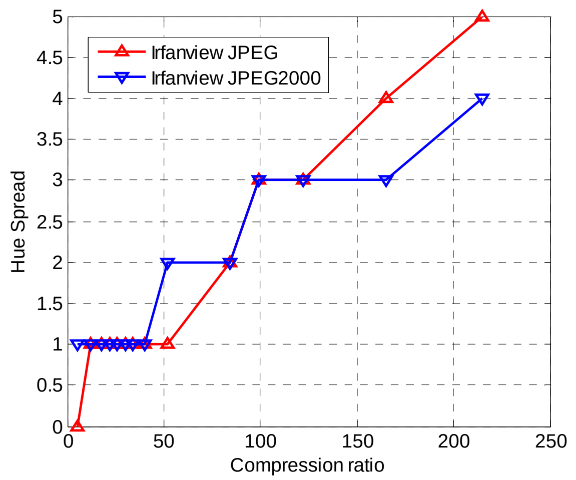

Figure 9(a) - The total hue spread of magenta for the Irfanview™ JPEG and JPEG2000 codecs.

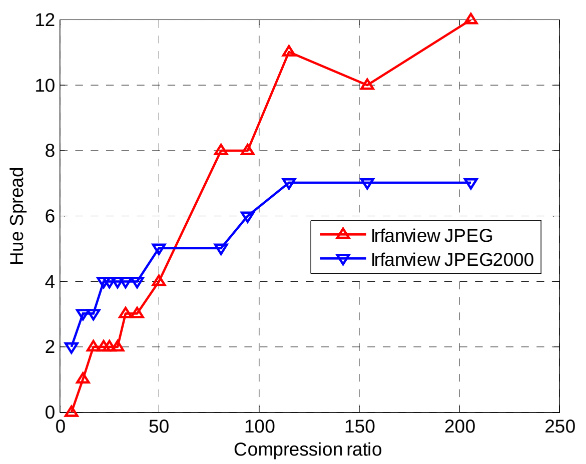

Figure 9(b) - The total hue spread of yellow for the Irfanview™ JPEG and JPEG2000 codecs.

5. DISCUSSION AND CONCLUSION

This paper analysed the cross effects of luminance on hue as non-linear distortion. The reconstructed hue test patterns show that there are significant hue errors.

The results show that yellow has high value for hue spread and hue shift compared to magenta. Yellow is a combination of green and red which have 58.7% and 29.9% contribution to the luminance for the intensity component. This could be due to the brightness of the yellow.

Figure 9(a) and figure 9(b) depicts that both JPEG and JPEG2000 codecs introduce increasing amount of hue spread with the increasing compression ratio. In general, JPEG2000 codec resulted in less hue errors for higher compression ratios with varying luminance compared to JPEG.

Figure 6(a), 6(b), 7(a) and 7(b) show the luminance effect on hue of reconstructed image is different for different colour. The relationship cannot be generalised that increasing luminance values for the same hue result in increasing hue errors. Some luminance values do not have hue errors which are shown in Figure 6(a), 7(a) and 8. This could be due to the fact that original R-Y and B-Y values fall on top of quantisation level exactly. Hence the reconstructed R-Y and B-Y values remain as the original values without introducing any hue or saturation errors.

6. FUTURE WORK

Experiments to be carried out using different step sizes of luminance (that is different values for each region in tessellation) and to observe the spread and shift for each colour test pattern. Then compare them with results presented in this paper to investigate that certain luminance levels will not introduce hue errors.

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